InP/InGaAs Carbon Doped DHBT –Growth, Process and Reliability

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InGaAs/InP double heterojunction bipolar transistors (HBT's) are of interest for several reasons. Compared to GaAs-based HBT's they have lower turn-on voltage, higher ft and fmax, high breakdown voltage, better power-added efficiency, and enjoy the higher thermal conductivity of the InP substrate [1], [2]. They are also of interest for high bit-rate optical links of 40 Gb/s transmitting circuits for fiber optic communication system, and its potential for OEIC integration. The base dopant commonly used for these HBT's is Be in MBE system. However Be out -diffusion is has reliability problem in InP/InGaAs HBT. In this paper, we will present the design, growth, process and reliability analysis of InP/InGaAs HBT.

C-doped DHBT's were grown by CBE and Be-doped single HBT's were grown by MBE. Si was the n-type dopant. The standard C doped HBT had a 1000Å abrupt InP emitter with $n=1x10^{18}$ cm^{-3}, a 25Å undoped InGaAs setback layer, a 675 Å InGaAs base with $p=4x10^{19}cm^{-3}$, a 500 Å InGaAs setback layer with $n=5x10^{16}cm^{-3}$, and a 3500 Å InP collector with $n=3x10^{16}cm^{-3}$, incorporating a $n=2x10^{17}cm^{-3}$ near the top to minimize current blocking effect. The graded base ($In_{1-x}Ga_xAs$ with $0.43<x<0.53$) and thinner collector was designed for higher Ft. The Be-doped HBT has a digital superlattice emitter grade, which has shown considerable Be-diffusion resistance compared to an abrupt design with spacer layer for InAlAs/InGaAs. Devices were fabricated using a standard mesa process. First, the emitter contact is defined and then the emitter mesa etched. This is followed by base contact photolithography and formation. The devices are then isolated by etching down to the sub-collector. Finally, a 2000Å passivation layer is deposited, and second metallization done to form the pads. Fig. 1 shows the SEM micrograph of a 3 x 10 µm2 HBT after the collector metalization. Fig.2 shows the dependence of *Ft* on the collector current (I_C) at a V_{ce} of 1.5 V. The peak *f* increases from 129 to 157 GHz when comparing the standard and graded base with thinner collector layers. Finally, the reliability studies of HBTs performed using similar stress conditions. Fig. 3(a) shows the room-temperature Gummel plot of a Be doped HBT stressed at T_A=125 C (T_J=236 C) and Vce=1.5 V, Jc=150 kA/cm^2. After 45 h of stress, Vbe0 increased by 0.17 V to 0.63 V, hfe@1E4 and Re dropped to 28.2, and 5.1 respectively, and nc increased to 1.29. The offset voltage increased by 0.2 V, consistent with the higher Vbe0. The rise in Vbe0 and nc is typical of Be diffusion. In contrast, C doped HBT in fig. 3(b) showed a stable collector current curve. After 60 h of stress at 225 kA/cm^2, Vbe0 and nc changed very slightly, from at 0.414 V to 0.412 V and 1.08 to 1.07 respectively. Re decreased from 10.2 to 9.6 and hfe@1E4 increased from 30.7 to 35.7. The base current ideality increased from 1.4 to 3.6 at low currents. This information is important in assessing the choice of dopant and design for the targeted HBT application.

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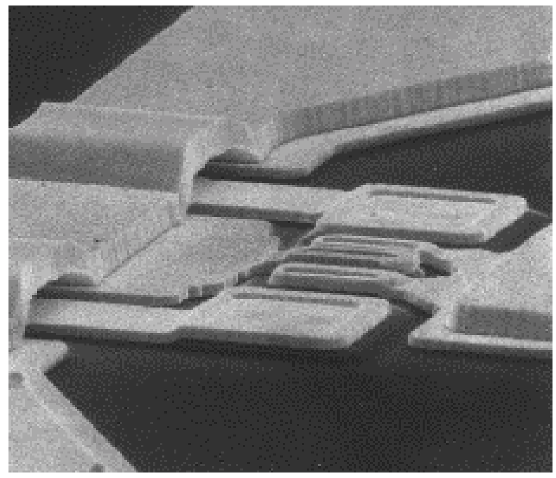

Fig. 1 SEM micrograph of a 3 x 10 µm2 HBT after the collector metalization. The emitter metal is in the center of the picture and is overlapped by the self-aligned base contacts. These contacts lie on the collector mesa. The isolation mesa is the large mesa with collector contacts on the right and left.

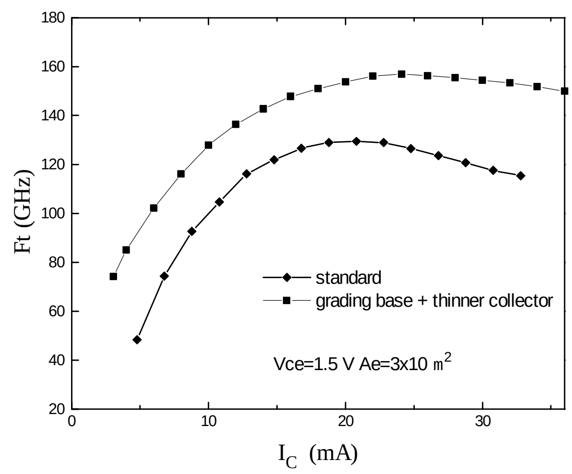

Fig. 2. The dependence of *Ft* on the collector current (I_C) at a V_{ce} of 1.5 V. The peak *f* increases from 129 to 157 GHz when comparing the standard and graded base with thinner collector layers.

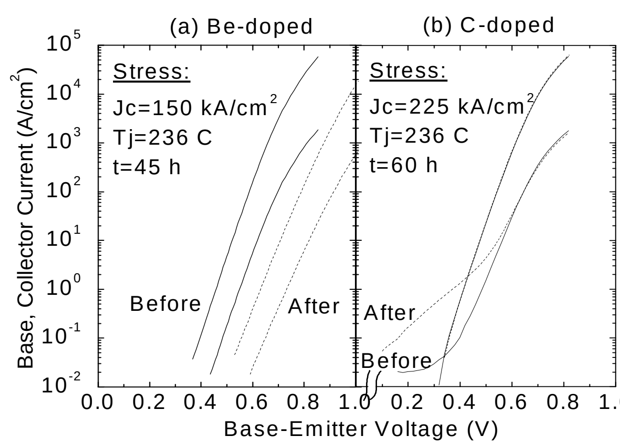

Fig. 3. Room temperature Gummel plots at Vcb=0 V of (a) Be (b) C doped HBTs before (solid) and after (dashed) elevated-temperature bias stress.